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AUTHOR	Beeth, Michael E.; McNeal, Betsy
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ABSTRACT

This paper describes attempts to explore a variety of questions about ways to integrate mathematics and science methods courses for preservice elementary teachers. Questions include: Are there principles of integration that can be used when planning the integration of courses? How might these principles help prospective teachers think about teaching in an integrated fashion? When and in what ways is integration appropriate? and What roles do the strengths of our individual courses play in an integrated structure? Two professors recounted their experiences in defining math and science with their co-taught class. (WRM)

Co-Teaching Science and Mathematics Methods Courses

by

Michael E. Beeth
Betsy McNeal

CO-TEACHING SCIENCE AND MATHEMATICS METHODS COURSES

Michael E. Beeth, The Ohio State University
Betsy McNeal, The Ohio State University

The teaching that we describe in this paper is part of a master's degree program leading to elementary teacher certification. Within this program, the development of literacy skills remains a central focus of teacher preparation, and integration tends to mean the subsuming of other subjects by literacy instruction. For that reason, we have been struggling against integration in order to ensure the integrity of our disciplines - mathematics and science. A number of factors have caused us to rethink our roles in the program. First, we also teach in an integrated secondary teacher certification program in Mathematics, Science and Technology Education (MSAT) that provides us with another model of integration, one in which the study of each discipline is strengthened by its integration with the others. Second, we have concerns about the quality of the math and science instruction that graduates of our elementary certification program might be offering their students and wish to explore alternative approaches to the integration of content.

The freedom to rethink our roles was facilitated recently when the administrative structures in the College of Education at The Ohio State University were reorganized. A consequence of this reorganization was that our teacher education programs were also adapted to fit the new administrative structures of the College of Education. Within the School of Teaching and Learning, the faculty formed three sections that offer M.Ed. teacher education programs. We (Beeth and McNeal) each are members of two of these sections, Integrated Teaching and Learning (ITL) which offers elementary certification and Mathematics, Science, and Technology Education (MSAT) which offers middle and secondary certification. The ITL section takes integration as one of its themes, where "integration" is broadly construed as the integration of teaching and learning, the integration of diverse students in one class, and the integration of subject matter, such as math and science. The M.Ed. programs that ITL runs prepare elementary teachers (K-8) with these forms of integration in mind. On the other hand, the MSAT section created a unique M.Ed. program that prepares prospective middle and secondary school teachers to integrate math, science, and technology into their teaching. Thus, our work as teacher educators in ITL and MSAT takes place within a climate of integration. We had broached the idea of integrating math and science to each other before this, but it was not until a colleague in drama education called us together to describe our courses to him that we realized how much common ground there might be.

The work that we describe here is work-in-progress as we explore a variety of questions about ways to integrate our science and math methods courses. Questions include: Are there principles of integration that we can use when planning the integration of our courses? How might these principles help our prospective teachers think about teaching in an integrated fashion? How much do we want to integrate (e.g., should we become one course, or come together only occasionally)? When and in what ways is it appropriate to integrate and when not? What roles do the strengths of our individual courses play in an integrated structure? As we attempt to provide our prospective teachers with situations in which math and science can be talked about together, we are attentive to themes that emerge in these discussions that might inform our future plans. Finally, as mentioned above, this work is literally "in progress" as the two courses are still under way and we are reporting on the first half of the coursework while we plan the second half.

The Methods Classes Prior to Integration

Each methods class meets weekly for two and a half hours over two ten week quarters, Autumn and Winter. We requested from our colleagues that the science and math methods classes be scheduled the same day in order to facilitate our efforts at integration. This report reflects only those activities that took place during the Autumn Quarter.

Science Methods Class -- Beeth

The goals of the elementary science methods courses are: 1) to motivate prospective teachers to want to teach science, 2) to confront prospective teachers' views of the nature of scientific activities and the implications these views have for teaching and learning science, and 3) to teach some fundamental science concepts. Beeth exposes prospective teachers to a model of instruction (Peterson & Jungck, 1988) that involves them in posing problems about natural phenomena, probing for answers that explain a problem, and persuading their peers that they have a sufficient answer to the question posed. Throughout this course prospective teachers participate in discussions designed to confront their notions of the nature of scientific activity and the implications that their views have for teaching and learning about science (see Moscovici & Nelson, 1998; Rutherford, 1987). Prospective teachers are expected to select teaching resources and plan instruction that is consistent with their developing view of the nature of science. The following excerpts from a former prospective teacher evaluation of the science methods course indicate the extent to which the first goal for this course was accomplished.

> I enjoyed the hands-on activities and most importantly, the instructors were able to improve my attitude and comfort level about science.

The second goal for these courses, to confront prospective teachers' views of the nature of scientific activities and the implications these views have for teaching and learning science, is as important as motivating them to include science in their instruction. Although many of the elementary and middle school students these prospective teachers work with are innately inquisitive about the natural world, capitalizing on this inquisitiveness is possible only if a teacher is well prepared to do so. Beeth's approach to helping prospective teachers in this course learn to think through these issues involved challenging their beliefs about the nature of science as an intellectual activity and modeling science instruction during his instruction. During this course Beeth modeled the 3 P's approach to science instruction (Peterson & Jungck, 1988). This model involved prospective teachers in: (a) POSING Problems about the natural world, (b) PROBING Problems with developing intellectual and physical abilities, and (c) PERSUADING

Peers that the results of their investigations were consistent with the data collected and well reasoned. This "3 P's" model presents science as an activity that starts with real world phenomena of interest to the learner. It includes an expectation that the learner will draw on his or her existing knowledge, additional resources such as library materials, the knowledge and expertise of other students, and the assistance of adults to collect information, analyze data, and present conclusions that provide an answer to the problem posed. This model places a heavy emphasis on the need to communicate the results of an investigation of the natural world in a persuasive manner (i.e., persuade peers). Developing the ability to probe problems and persuading peers are two characteristics of the 3-P's model of science instruction that stand in sharp contrast to more traditional presentations of a "scientific method."

Implemented in an elementary classroom, the 3 P's model allows teachers and students the opportunity to participate in many of the physical and intellectual aspects of science rather than just learning about the science someone else did years ago (i.e., the science of "dead white men"). This approach also includes a number of added benefits to the classroom teacher. One benefit of this model is that learners must communicate the rationale for what was done and what they learned, as opposed to merely following directions supplied on a worksheet to fill in predetermined blanks or data tables. This allows teachers opportunities to reinforce the necessity for teaching written, oral, and visual communication skills -- skills that elementary school teachers traditionally teach well and ones they can reinforce in the context of student-designed investigations in science. Another benefit of this model is that it removes the apprehension some teachers feel regarding knowing too little science content in order to teach a subject well. Using a 3-P's approach, students generated their own problems and the solutions to them. While learning science content is an expectation of the model, it is not an expectation that students at this age will possess "the received view" of any particular body of scientific knowledge.

An additional benefit of the 3 P's model to an elementary school teacher is that he or she can address aspects of science that are external to the science content itself. For example, how does the background of an investigator effect the outcome of an investigation? It is well known historically that the nationality of an investigator does influence what they identified as a problem to be solved, who they considered to be colleagues working on similar problems, and how data are presented. For example, evolutionary biology is filled with instances of scientists working along nationalistic lines (e.g., followers of Frenchman George Cuvier attempting to prove the intellectual superiority of white male Europeans). In a similar vein, the influence of elementary and middle school age students' past experiences, as well as their current beliefs, attitudes, and values, effect the interpretations they make about investigating the natural world. The influences of individual factors such as these can be used to discuss issues related to social aspects of learning science (e.g., who did this science?, where did it occur?, and why did they get to do it at that time?). More contemporary issues of science might also be discussed such as would the availability of better technology affect your science investigation, and if so, how?

Another benefit of 3 P's instruction is that it relies on the group to determine what is accepted and what is not. Since persuasion of peers is a requirement of this instruction, the group establishes norms for what counts as an acceptable explanation without dismissing the possibility that an individual may have his or her own ideas. Investigations presented within the scientific tradition do require that multiple investigations produce the same results if the conclusions are to be considered valid. This is not to imply that scientists are somehow seekers of an objective truth. It is meant to communicate that socially accepted standards of scientific inquiry do exist, regardless of the background of a particular scientist. Generating these standards is a significant aspect of the learning that can occur when a 3-P's approach is followed. The statement that follows is indicative of the impact that this model of instruction had on prospective teachers in the science methods course.

> I felt I learned a lot about how science is done and I feel it's an important concept for kids to learn.

The final goal of instruction in this methods course was to teach some science content. Granted, teachers at all levels can always benefit by learning additional science content. Throughout the course, lessons were chosen to included content that focused on fundamental concepts in science. Prospective teachers explored the concept of density by placing cans of carbonated soda in water to determine why some sank while others floated. They also observed and described physical variation in human genetic traits followed by a lesson on genetics (Soderberg, 1992). After learning to plant and grow Wisconsin Fast Plants©, prospective teachers posed problems about plant growth and which factors we could investigate in the classroom. Beeth selected science content for this program only if it engaged students in learning processes he associated with science (exemplified by the 3 P's model of instruction) and it had the potential to be highly motivating to the prospective teachers.

At the beginning of each class period, Beeth provided prospective teachers with examples of prepared instructional programs and references to the availability of free or inexpensive instructional resources. On the last class day, he talked about local, state, and national science teacher organizations and encouraged prospective teachers to continue pursuing a knowledge of science through formal means, such as taking a science content course, and informal means such as attending bird or flower hikes in local parks. Science content was not the main focus of Beeth's instruction since it is quite literally impossible to cover the amount that prospective teachers might need. Although Beeth sacrificed breadth of coverage, prospective teachers, like the one below, did indicate that they had learned some concepts well enough to teach them.

> I enjoyed many of the experiments and group activities we did in class and hope to use some in my own classroom, especially the marshmallow meiosis which illustrated how traits are passed from one generation to the next.

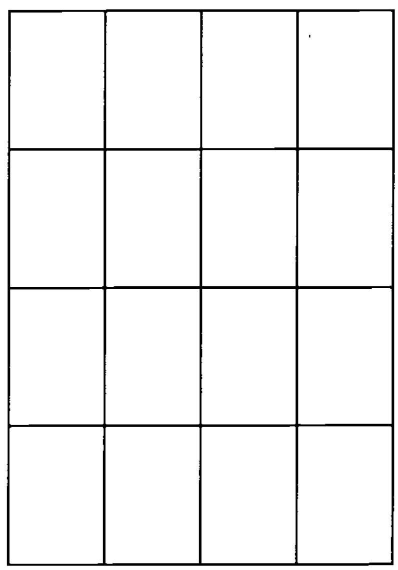
Evaluations of the science methods courses by the prospective teachers indicate substantial accomplishment of Beeth's instructional goals. So why mess with a good thing? Why begin the process of integrating science and mathematics when things seemed, from the prospective teacher's point of view, to be going so well? A partial answer to this question is that science instruction, even at its best, would not help our prospective teachers experience the integration of these subjects, and we felt that this experience was essential for them. Although most of the faculty in the ITL programs say they do integrate multiple subjects, no one had yet taken the steps that would capitalize on what we all thought could be an even better experience for our prospective teachers.

Mathematics Methods Class -- McNeal

McNeal views learning to teach as a lifelong process of personal reflection on theory, practice, and their interrelationship and explicitly states that this course "will not teach you how to teach mathematics ... This course ... aims instead to teach you how to LEARN about teaching and learning mathematics" (McNeal, Ed T & L 708 syllabus). The main goals of this two-quarter course are to support prospective teachers in: 1) examining their assumptions about mathematics, mathematics teaching and learning; 2) learning about current issues in mathematics education; 3) listening to and observing students' thinking; 4) planning lessons that build on what students' know; 5) evaluating their own lessons in terms of what learning occurred; and 6) viewing teaching as inquiry -- there are dilemmas in taking a problem solving approach to mathematics instruction that each individual teacher must resolve in the particular context of his or her school and community. The first three goals form the primary thrust of the Autumn Quarter, while the last three are emphasized in the Winter Quarter.

Along with asking prospective teachers to describe their relationship to mathematics and to read articles that provoke them to think about what it means to understand mathematics, McNeal engages prospective teachers in doing mathematics and then in reflecting on that experience in the hope that these activities will challenge some of the ideas that prospective teachers often bring to their thinking about teaching. For example, most prospective teachers believe that mathematical problems are solved by applying a best procedure (usually one expressed as a formula) to generate a single answer. Their experiences in mathematics class were often limited to listening to the teacher present a procedure, then practicing that procedure, and having their answers validated by the teacher. In McNeal's class, prospective teachers solve a carefully selected problem in pairs and then participate in a discussion of the solution methods used. For example, the "squares problem" in Figure 1 was the first problem introduced in the math methods course (see Table 2). Initially, prospective teachers often see only 16 squares, then recognize the outside border of the grid as another square and their exploration takes off. The object of this problem was to help prospective teachers recognize the existence of a variety of solution methods and problem interpretations to an apparently straightforward problem. In moving on to an 8 by 8 grid, prospective teachers usually want to generate a more systematic method of counting, or of computing, the number of squares. This elicits a search for patterns and the generation of formulae to express those patterns. McNeal facilitates the discussion to highlight the variety of methods and the different interpretations taken, and simultaneously makes a concerted effort to avoid evaluating the prospective teachers' answers as right or wrong. By these means, McNeal challenges the prospective teachers' current conceptions of mathematics, mathematics teaching and mathematics learning.

Figure 1.
The "squares problem."
How many squares do you see in this picture?
If we call this a 4 by 4 grid, how many squares would there be in an 8 by 8 grid?



Over the 10-week quarter, the class moves from these foundations (discussion of and about mathematics, the goals of teaching mathematics, and factors that help and hinder mathematical learning) into more specific discussion of children's ways of thinking about and doing the mathematics of counting, place value, addition, subtraction, multiplication, and division. Discussion of the connections among these mathematical ideas and operations is generated once again by engaging the prospective teachers in doing mathematics. They are introduced to counting in base 8 and asked to operate completely within that system as they solve arithmetic problems as if they were children. Rather than requiring prospective teachers to role play, the base 8 system challenges them to rethink basic arithmetic, counting, and place value. The computational strategies generated by the prospective teachers often replicate methods that young children use to solve arithmetic problems and hence these experiences help prospective teachers to understand both the learning experiences of children and the mathematics involved in the operations that seem self-evident to them as adults. Other topics in mathematics, such as fractions and data analysis, are dealt with in the Winter Quarter, using similar pedagogical strategies.

Looking for a Workable and Reasonable Integrated Structure

We began our joint planning by meeting to discuss our current, separate course goals and assignments in order to find common themes and/or activities from which to begin the process of integration. This included discussion of what we would mean by "integration". For instance, McNeal was initially considering integrated assignments (assignments that would count for both courses) as well as combined class sessions.

As we outlined the goals discussed in the previous sections, we found that our separate courses developed parallel strands of discussion on the nature of math and science in the early weeks of the quarter. Not surprisingly, each separate methods course also included some work on children's development of subject matter understanding and lesson planning. Because of similarities in our own conceptions of science and mathematics that included a focus on inquiry and the relationship of each to the other (math as a useful tool for scientific investigation and science as an application of math), we planned to engage the prospective teachers in activities that would exemplify integrated lessons.

We also found that our course emphases were complementary in that Beeth had prospective teachers begin planning lessons in the Autumn Quarter, then moved to a focus on children's conceptions of science in the Winter Quarter while McNeal did the reverse, making lesson planning a major area of discussion in the winter, after focusing most heavily on children's conceptions of mathematical objects and operations in the autumn. This complementarity had two effects on our thinking about integration: First, it meant that our assignments did not readily mesh so we abandoned that idea, and second, it suggested another way of thinking about the integration of our courses. Furthermore, we thought that prospective teachers, like elementary students, might benefit from working on lesson planning and learning about children's subject-specific conceptions over time. By engaging prospective teachers in thinking simultaneously about lesson planning and about children's learning over time, but not in the same content domain, we hoped to allow them some room for depth and enrichment. Specifically, we hoped that prospective teachers' developing ideas about planning science lessons might enrich their math lessons and that their developing awareness of how to look and listen to children's mathematical understandings might inform their thinking about children's scientific conceptions.

By thinking of the two courses as interwoven rather than running in parallel or as one single course, we came up with a simple structure. Out of a total of ten sessions in autumn, we decided on three non-consecutive joint sessions around the following activities: discussion of prospective teachers' understandings of the nature of math and science, and two activities that integrated math and science (a technology lab and an investigation of density). The simplicity of this structure, one that was not radically different from the usual, neither consumed too much of our energy and time in integration, nor detracted from meeting the goals of our separate courses. Table 1 displays the planned integration of joint sessions with existing math and science lessons. Reading the second, third, and fourth columns shows the math syllabus, and reading the sixth, seventh, and eighth columns shows the science syllabus. The middle column (Science and Mathematics) shows the topics for the integrated sessions.

Table 1

Planned Integration of Math and Science Courses

Date	Math class topics	Math class activities	Math assignments	**Science and Mathematics**	Science topics	Science class activities	Science assignments
Week One 9/29	Assumptions and expectations about math, teaching, & learning based on your prior experiences	squares problem in-class write up of mathematica l thinking	Holt (131-191)		Your past experiences in science	Fast Plants	
Week Two 10/6	Conceptual vs. procedural knowledge; How we learn ; Goals of math education	in-class write up of mathematica l thinking	Skemp Erlwanger Due: Reflection		Your past experiences in science		Peterson (1988) Science autobiograp hy due

Week Three 10/13	Beliefs about what math is; Comparison to math in school	meet in morning with science	Tate Standards Due: First field journal; Reflection	**Discussion: compare and contrast: what is science? what is math?**	Posing authentic questions		Rutherford (1987)
Week Four 10/20	Writing in math; Looking at children's math	video; discuss 1st field journal; prep for 2nd field journal	Wilde Pengelly O'Brien Due: Reflection on math/science		Posing authentic questions		Watson (1990)
Week Five 10/27	Technology in math class; Integrating math and science	meet in a.m. with science	Curcio & Folkson; Penniman; Isaacs & Kelso Due: Reflection; Second field journal	**Calculator-based graphing; Ideas for integrating science/math; using technology in the classroom**	Role of Science in the Elementary School	Magic or Science?	web links

Week Six 11/3	Children's arithmetic; Counting; Word Problems	Base 8; Cognitively Guided Instruction (CGI)	Cobb & Merkel; Carpenter et al. Due: Reflection on math/science		Role of Science in the Elementary School	Sinking and Floating	Instructional resources due
Week Seven 11/10	Hands-on to generalized formula/strategy	meet in a.m. with science	addition/subtraction readings; finish Holt Due: Reflection	**Density lab; Discussion of ways to build a formula**	Integration of Science et al.	Sinking and floating	Hewson (1998)
Week Eight 11/17	Continue counting; Addition & subtraction; Place value	more base 8; text pages; context of learning	Labinowicz Due: Lesson plan, transcript; Reflection on math/science		Integration of Science et al.		McLeod (n.d.) Science lessons due
Week Nine 11/24	Multiplication & Division	more base 8; word problems	Kamii; Burns Due: Reflection		Learning Science Concepts	Marshmallow Meiosis	Gatto (1993)

Week Ten 12/ 1			Ball Due: Reflection; Child study		Learning Science Concepts		Soderberg (1992)

What Really Happened

Our first joint session took place in the third week and dealt with the prospective teachers' conceptions of the nature of mathematics and science. We planned this to follow two weeks of instruction in each separate course. As can be seen in Table 2, during this time, we were laying the foundations for discussing the nature of mathematics or science, independent of one another. Our intention was then to bring our courses together to see what sense the prospective teachers would make of the two disciplines. We facilitated discussion around similarities and differences in the hopes that this would enrich their understanding of each discipline separately and begin to develop a sense of the relationship of each to the other. An analysis of this discussion follows below.

Our second planned session was the technology lab. We invited two teachers who teach velocity and acceleration to Kindergarten students using a calculator-based lab to model this activity, and hence the integration of math and science, to the prospective teachers. Because we were unable to coordinate our schedules during the Autumn Quarter, this did not occur. We hope to make this work in the Winter.

Our third planned session was the density lab conducted by Beeth. The intent was to develop both a definition of density and an understanding of density as a mathematical relationship between mass and volume. The prospective teachers explored the concept of density by placing cans of carbonated soda in water to determine which sank or floated. The difficulties we experienced in trying to teach this joint session will be discussed in the final section of this paper.

Table 2

What actually occurred.

Date	Math class topics	Math class activities	Math assignments	**Science and Mathematics**	Science topics	Science class activities	Science assignments
Week One 9/29	Assumptions & expectations; Relation to prior experiences	squares problem math writing	Holt (131-191)		Your past experiences in science	Fast Plants	
Week Two 10/6	Conceptual vs. procedural knowledge; How we learn; Goals	discussed squares; discussed readings	Skemp Erlwanger Due: Reflection		Your past experiences in science		Peterson (1988) Due: Auto-biography
Week Three 10/13	Beliefs about what math is; Comparison to math in school	met in a.m. with science	Tate Standards Due: 1st field journal; Reflection	**Discussion: compare and contrast: what is science? what is math?**	Posing authentic questions		Rutherford (1987)

Week Four 10/20	Writing in math; Looking at children's math	discussed Standards; shared observations; clear lake problem	clear lake Wilde O'Brien Due: Reflection on math/science		Posing authentic questions		Watson (1990)
Week Five 10/27	Integrating math and science	met in a.m. with science	Campbell et al. Finish Holt Due: 2nd field journal	**Density lab -- hands-on experiments; discussed meaning of density**	Role of Science in the Elementary School	Magic or Science?	web links
Week Six 11/3	Children's arithmetic; Counting	base 8; CGI	Cobb & Merkel; Carpenter et al.		Role of Science in the Elementary School	Sinking and Floating	Instructional resources due

Week Seven 11/10	Continue counting; met in a.m. <u>without</u> science	base 8 activities; discussed basic facts; video of children's addition strategies	Due: Reflection		Integration of Science et al.		Hewson (1998)
Week Eight 11/17	Addition & subtraction; Place value; Word problems	text pages; base 8 activities; video of subtraction strategies; shared lessons	Labinowicz Due: Lesson plan & transcript		Integration of Science et al.		McLeod (n.d.) Science lessons due
Week Nine 11/24	Multiplication & Division	solving 59 x 69 mentally; mult. & div. word problems	Kamii; Burns Due: Reflection		Learning Science Concepts	Marshmallow Meiosis	Gatto (1993)

Week Ten 12/1	Word problems & CGI; Dilemmas in teaching	solved word problems by modeling; shared case studies; discussed dilemmas	Ball Due: Child study		Learning Science Concepts		Soderberg (1992)

Discussion of the Nature of Science and Math

Prior to a joint discussion of the nature of science and math, Beeth had asked the prospective teachers to choose a definition of science from among six possibilities (see Figure 2). While McNeal had engaged the prospective teachers in doing non-routine mathematical problems and in discussing how these experiences differed from their prior experiences with mathematics as described in an earlier section, she had not engaged the prospective teachers in explicit discussion of the nature of math. When Beeth shared the science definitions with McNeal during the planning sessions, McNeal thought they would be provocative in a discussion of the nature of mathematics. On the morning of our joint session, half of the class was asked to look at the science definitions again and to choose any that they felt applied. The other half of the class was asked to consider the question, "What is math?", and were encouraged to use the list of definitions of science to assist them. We then facilitated a discussion comparing and contrasting their definitions of both, but beginning with some of the group's definitions of math.

Figure 2
Definitions of science presented in Beeth's class

SCIENCE IS:

• A BODY OF KNOWLEDGE that includes the names of organisms and their parts, the laws that govern the natural world, and theoretical ideas.

Learners of science should know as much of this body of knowledge as possible -- the anatomy and physiology of objects in the natural world.

• GENERATING NEW KNOWLEDGE about the natural world -- scientists discover new organisms and find out things not previously known.

Learners should understand the methods and procedures used by scientists when they set out to discover new things.

• A SET OF IDEAS (i.e., concepts) that allow people to explain how the natural world works.

A learner should be able to persuade others that he or she understands the natural world, and that his or her understanding is compelling.

• SOLVING PROBLEMS that are important to an individual or significant social problems such as reducing the impacts of pollution, finding cures for diseases or making better/more efficient products.

Learners should be able to apply their understandings of science problem solving to improve the quality of their lives.

• ONE PART IN THE HISTORY OF HUMAN DEVELOPMENT -- science has a long history, a complex sociology, and a deep philosophy.

What is important is that a learner understands the conditions under which scientific knowledge is generated, and how the production of this knowledge impacts the lives of non-scientists.

• A CHANGING SET OF IDEAS -- scientists will study the same natural objects and phenomena they always have but how we think about the natural world today needs to be an open question (i.e., changes in scientific ideas about the relationships between earth and sun have drastically changed the way we think).

A learner should understand that all scientific knowledge is tentative, and, when changes occur, how and why that knowledge changed. Upon what criteria or new information does the scientific community change its ideas?

This was a lively and lengthy discussion, lasting about an hour and a half. Over that time, the prospective teachers' ideas seemed to move from one word definitions of math illustrated immediately below to much more complex definitions of math (and science as well). This development occurred through a variety of connections made by the prospective teachers. They initially drew on experiences with math in their everyday lives prior to entering the program, such as learning percussion or dance, in order to exemplify their definitions. Later they began to make connections to experiences from our courses such as the "squares problem".

CL: We said that math is critical thinking, problem solving, reasoning and patterning. Math isn't a set of changing ideas -- the process changes but the product is not negotiable . . . Math is patterning, then we thought of math as musical because of my experiences playing percussion. I thought in eighths and sixteenths.
AN: (from another group) Yes, I had that experience with dance!
MP: (questioning CL's group) Does the product or answer ever change?
EG: [mentions that there can be different answers to the squares problem and other open-ended problems]
JN: Some answers aren't the same because the assumptions are different.
EG: For the purpose of communication, there has to be <u>some</u> stuff that is understood.

Embedded in this conversation is the prospective teachers' belief that the purpose of mathematics is to obtain correct answers. For the prospective teachers, this represents an unchanging, or absolutist, view of mathematics. As the conversation continued, they contrasted their view of the nature of mathematics to their view of science that they indicated was a changing set of ideas.

BA: I saw math before this as <u>finality</u>, one answer, but maybe infinite ways to solve. If there's more than one answer, then I don't want to learn math. It doesn't make sense to me that there could be more than one answer.

MP: That goes back to how we were instructed, how secure we feel with one answer. We weren't allowed to explore.

The prospective teachers' statements here suggest that they are beginning to see their ideas and feelings about the nature of mathematics as related to their prior experiences. They continue to build this connection as the conversation is switched to one group's ideas of the nature of science.

AH: [Our group] thinks science is a changing set of ideas. We are still thinking about the same things as 100 years ago, but changing the answers. We are changing the methods too.

Beeth: You seem to be saying that it's OK for science to change. Is it not OK for math ideas to change?

MB: It might be OK for math to change, but I would need some kind of proof. Science has data to show [that the ideas should change.]

NR: It would be hard to replicate a science experiment if math changed as well.

ME: Science is much more complex. Math is more concrete, I mean, $2 + 2 = 4$.

EG: We don't want to see math as a process because it's uncomfortable.

Bednar [a Clinical Educator assigned to the science methods course]: I see lots of parallels between math and science. You can have different answers in math. $1 + 1$ could be 10 if each 1 is 5 things clumped together. It's not simple for children at all. Both [math and science] are process-oriented. Educators need to look at how we view [math and science] or what views we pass along.

HM: We have to be careful when we say that science is a changing set of ideas because lots doesn't change.

SB: We're used to science changing. I can see science has changed, but I can't see this in math.

The prospective teachers' statements about the nature of science indicate their understanding that it is a changing set of ideas, and that this view of science fits with their experiences. This stands in stark contrast with their view of mathematics as expressed earlier. Dissatisfied with the idea that science and math might be different, the prospective teachers shifted the conversation to the implications of their understandings of the nature of math and science for school science and math.

> SH: I think math and science ask different questions. In math we [teachers] tend to ask the same questions over and over, but in science, we are more open-ended. I resist math because I don't want people to tell me what the question is, I want to ask my <u>own</u>. [If I hadn't read the Tate article] I never would have thought to pose a question like how to show the effect of liquor stores in my neighborhood.
>
> MP: I think it's a difference in higher level math versus elementary. In elementary math, there are different processes, but the same answer. In elementary science, the questions <u>are</u> more open.
>
> MB: Is Pluto still a planet? If it isn't, a change like that will affect how we teach science.
>
> Beeth: In science we seem to think it's OK to have two ideas, like the behavior of light being like both a particle and a wave. Science is willing to live with this duality.
>
> AF: Even if we let children ask their own questions, there are still right answers.
>
> SH: There is lots that can trouble the factuality.
>
> Beeth: Is science much less precise than math? All questions are possible.
>
> SH: Math <u>should</u> be that way.
>
> McNeal: Maybe we need to make a distinction between school math and math as a discipline. My husband [a mathematician] seems to feel that he can ask any question that he wants!
>
> HM: In school, math worksheets only have problems like 5 + 2. We see math as just numbers, there is no context. In science, the question tends to be "why?" In math, the question tends to be "what is the answer?"

<u>Implications for Further Co-Teaching of Science and Math</u>

In having this discussion around the definitions of math and science, we were trying to give prospective teachers some tools (e.g., definitions of science and the squares problem) for talking about math and science that they may not have experienced. As instructors, we were also hoping to create dissatisfaction in them about their beliefs about math and science. We noted that the prospective teachers drew on the single example of the squares problem for discussing mathematics, but were able to generate multiple contexts/problems for discussing science (e.g., Pluto, genetics, light) from their own experience. This seems to have been sufficient for the prospective teachers to move from rhetorical statements about science and math, to thinking about their own experiences, to feeling dissatisfied with their current views, and to considering how they would teach math and science.

We were very pleased with the value of this discussion of the nature of science and math. We saw a parallel between the existence of multiple definitions of science with the multiple solution methods for a given math problem. It seemed that contrasting math with science enabled the prospective teachers to look more closely at mathematics as a discipline, recognize their own views of mathematics as absolutist, and finally, of the relationship these views had to their prior experiences.

Despite the value above, we experienced a number of difficulties with co-teaching these courses. Among these were our lack of knowledge of each other's teaching styles. This showed up most readily during the density lab. In discussing and then choosing to do this lab, we thought we saw interconnections between the science and the math that would be easy for us to bring out jointly. This did not happen. Although the lab was successful in terms of learning for the prospective teachers (based on their written reflections on this experience), Beeth taught this lab as he had taught it in the past with little input from McNeal. In the process of this paper, we were finally able to articulate our miscommunication around this lab. McNeal had been expecting an activity that would engage the prospective teachers in empirically deriving a formula and had continually interpreted Beeth's description of the lab as such. We now understand that the formula for density is a logically derived from definitions, rather than empirically from data. This distinction between how formulas are derived will help us choose activities in the future that demonstrate both types of interconnections.

This was our first stab at integration -- our prospective teachers are still trying to figure it out, so are we . . .

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Signature: Michael E. Beeth	Printed Name/Position/Title:	
Organization/Address: Ohio State University 333 Arps Hall/1945 N. High Street	Telephone: 292-5377	FAX: 292-7695
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